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A number of bistatic synthetic aperture(SA) imaging techniques applicable to short wavelength radiation have been analyzed, and near real time two-dimensional SA imaging using visible light has been demonstrated.

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SYNTHETIC APERTURE IMAGING TECHNIQUES AT SHORT WAVELENGTHS

Environmental Research Institute of Michigan
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FINAL REPORT

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Author and Principal Investigator:	Carl C. Aleksoff

STATEMENT OF THE PROBLEM STUDIED

The goal of this study was to theoretically develop and experimentally investigate synthetic aperture (SA) imaging techniques applicable from the visible to submillimeters wavelength region of the spectrum (i.e., "short" wavelengths in the interval of 0.4 m to 1 mm). In this short wavelength region it is assumed that only intensity (square law or photon) detectors exist, and hence, that the amplitude and phase of the scattered radiation can not be detected directly as with SA microwave radars. Two dimensional imaging was to be demonstrated using whatever SA data gathering techniques are applicable for this short wavelength region, e.g., interferometric, ranging, doppler, etc. Emphasis was to be on multi-static configurations, i.e., where source(s) and detector(s) are physically separated by significant distances.

SUMMARY OF RESULTS

We have developed a number of different synthetic aperture (SA) imaging techniques applicable to short wavelength radiation. The SA data can be obtained using doppler, interferometric, or ranging techniques in bistatic configurations. The synthetic aperture data history can be realized through relative motion between the object and the sensor system. In a broadened context of SA concepts, the use of temporally modulated signal transmission or the use of a scanning illumination beam can also provide an extended received signal history which may be processed for high resolution performance. A critical feature is designing the proper system configuration and SA format that simplifies the subsequent data processing, i.e., imaging. In fact, for example, the development of polar formatting for SA imaging of rotating objects overcame a previous limitation in resolution that was, in essence, limited by the difficulty of processing.

We have typically emphasized interferometric SA imaging at visible wavelengths with proper formatting for subsequent optical processing via holographic techniques. In such an interferometric SA system it is the instantaneous relative position of the object in the interference field that determine the position of the instantaneous data point in the SA. In general, good two-dimensional imaging requires a combination of field scanning along with object motion in order to fill the SA. The recorded SA data is simply the intensity of the scattered light from the object as detected with a large area detector. In the ideal situation the SA data is in holographic form and the image is formed by simply illuminating the SA with a proper reconstruction wave.

A laboratory for demonstrating SA imaging in visible light was assembled under this grant's funding. Special electronics, interferometer, translation stages, rotating tables, optical modulation, and polar format film recorders were part of the system. Accurate registation between the relative position of the object to the interference field and the data point position in the SA was the most difficult requirement. Successful SA imaging was demonstrated for objects with linear motion and that for objects with rotating motion.

In the early stages of the work, the SA data was recorded onto photographic film with a laser beam, the film was next developed, and then illuminated (as a hologram) to construct the image. In the latter stages of the grant, a near real time SA system was demonstrated. Here the SA data was directly electronically written onto a thermoplastic light modulator (TLM). (The TLM is a two-dimensional spatial phase-modulator that uses an electron gun to write the data onto the thermoplastic as a charge induced deformation.) The TLM was the input transducer to a coherent optical processor and was set up to receive data directly from the laboratory as it was being generated for a rotating object. The image could be observed to form in real time in the output plane of the processor.

SA imaging for the case of generalized object motion suggests that extension of processing techniques to a third dimension may be quite useful and possibly essential. Though algorithms for this purpose were not established, it is expected that such processing could be handled digitally (and possibly with future special-purpose hybrid processor designs. As we demonstrated, certain relative motions, such as linear or circular, are elegantly and efficiently handled with presently available optical processing methods.

In conclusion, we point out that we have analyzed a number of different bistatic SA imaging techniques applicable to short wavelength radiation and have experimentally demonstrated near real time two-dimensional SA imaging using visible light.

APPENDIX
PUBLICATION LIST

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